Clinical Investigation

Nd-YAG Laser in Lung Cancer

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We administered 45 Nd-YAG laser treatments in 29 patients (18 men) aged 39 to 82 years who had lung malignancy; 26 patients had primary non-oat cell lung cancer and three had metastatic airway malignancy. In all, 25 of the patients had been previously treated with combination(s) of surgical procedure, radiation therapy and chemotherapy. Indications for laser treatment included endobronchial airway obstruction with uncontrolled cough, hemoptysis, dyspnea or unresolved atelectasis-pneumonia. Of 15 patients with partially occluded tracheobronchial airway tumors, immediate palliative relief was achieved in 13 patients and lasted one to six months after a single treatment. In this group there was one postoperative death related to respiratory failure and two patients subsequently died of massive pulmonary hemorrhage. However, of 14 patients with totally obstructed airways, immediate palliative relief was achieved in only five patients and this lasted three weeks to three months after a single treatment. In this group there were two postoperative deaths related to progressive respiratory failure; in one case it was associated with endobronchial combustion of the fiberoptic bronchoscope. All three patients in both groups who died of respiratory failure were in acute respiratory distress and terminally ill before the procedure. These findings suggest that Nd-YAG laser therapy may be most beneficial in patients with partially rather than totally occluded airways due to lung malignancy.

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Recently, European investigators[1-3] have reported the use of the neodymium-yttrium-aluminum-garnet (Nd-YAG) laser for treatment of tracheobronchial obstruction due to tumor and for tracheal stenosis. However, these reports have not clearly identified the cell type, location or extent of tumors, previous therapeutic approaches, lung function and complications. To better assess the effectiveness and value of this new palliative modality, we herein document our experiences with the treatment of malignant tracheobronchial tumors. Results indicate that the Nd-YAG laser treatment may provide immediate palliative relief for up to one to six months in 87% of patients treated for incomplete malignant airway obstruction, as opposed to 36% improvement with complete malignant obliteration of the airway.

Materials and Methods

The Nd-YAG laser (Medilas, MMB, Endo-Lase, Inc, Washington, DC) generates timed output of up to 80 W in the infrared wavelength—1,064 nm—which is conducted by a flexible quartz monofilament. This filament may be passed through either the biopsy channel of a wide-channel fiberoptic bronchoscope (Olympus Model BF-1TR) or a rigid bronchoscope. Because the laser beam is invisible, a companion helium-neon beam is simultaneously transmitted that projects a red spot, allowing accurate aiming. A continuous flow of compressed air is passed simultaneously through a coaxial Teflon sheath to keep the tip of the fiber cool and free of debris.

In practice, we use power of 40 to 60 W with an individual pulse time of 0.4 to 0.7 seconds in bursts

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ABBREVIATIONS USED IN TEXT

FEV_1 = forced expiratory volume at one second
FVC = forced vital capacity
Nd-YAG = neodymium-yttrium-aluminum-garnet
SD = standard deviation

every two seconds, with a target distance of 5 to 10 mm. The laser beam has a divergence of 10 degrees, such that the circular treatment area is 1 to 2 mm; 40 W is used for coagulation of tissue or bleeding vessels, whereas higher wattage results in vaporization and excision. Each pulse of the laser is triggered by a foot pedal controlled by the bronchoscopist, and the power and time duration is recorded for permanent copy in addition to digital display. To avoid retinal injury, the bronchoscopist and attending personnel wear special goggles.

All procedures are carried out in an operating room with an anesthesiologist present. Most procedures are done on an outpatient basis with same-day discharge. Patients are requested to refrain from eating or drinking for at least 12 hours before the procedure. Preoperative intramuscularly given medication consists of atropine sulfate, 0.6 to 1 mg, 50 to 75 mg of demerol and 25 mg of hydroxyzine hydrochloride (Vistaril). Topical airway anesthesia is achieved with 0.5% tetracaine hydrochloride (Pontocaine) and for adequate sedation intravenous administration of diazepam and the use of other muscle relaxants may be required. In selected patients who have malignant lesions involving the trachea, carina or main stem bronchi, general anesthesia and rigid bronchoscopy are used. Inhalational anesthetics include thiopental sodium (Pentothal), nitrous oxide and enflurane. Enriched oxygen up to 100% has been required in selected patients. In practice we have used the flexible fiberoptic bronchoscope to deliver the laser beam in every patient, and when necessary it easily passes through the rigid bronchoscope. An endotracheal tube, when present, facilitates the passage of the fiberoptic bronchoscope. Coagulated and necrotic tumor when not vaporized is removed through the biopsy channel or rigid bronchoscope using aspirator or biopsy techniques.

We administered a total of 45 laser treatments in 29 patients (18 men) aged 39 to 82 years, all of whom had biopsy-proved malignancy. Indications to give the laser treatment included (1) obstructed airway with unresolved distal atelectasis with or without pneumonia or abscess, (2) associated uncontrolled cough, (3) unrelenting dyspnea and (4) uncontrolled hemoptysis in patients who were previously treated with other modalities or who refused other forms of treatment. Detailed informed consent was obtained in each patient, consistent with guidelines from the Food and Drug Administration, California Patient Bill of Rights and the local hospital institutional review committee. Immediate palliative improvement was determined by recannulation of previously obstructed airway with relief of dyspnea and cough, hemoptysis or atelectasis-pneumonia. Isolated recannulation of an airway without clinical, radiographic or physiologic improvement was not judged to be a successful result. In all patients who had atelectasis, it was present radiographically for less than a month.

Before laser therapy we measured a patient's Dyspnea Index.[4] Briefly, a Dyspnea Index of 1 is shortness of breath only on stair climbing; 2 is inability to walk a mile on level land at a normal pace; 3 is shortness of breath on walking 90 m (100 yards) on level land, and 4 is shortness of breath with slight exertion after dressing or talking. We also measured the Karnofsky score.[5] Briefly, a Karnofsky score of 10% to 20% is consistent with total inability for self-care and total confinement to bed or chair; a score of 30% to 40% is consistent with confinement to bed or wheelchair 50% or more of the waking hours; a score of 50% to 60% is consistent with self-care and ambulation but inability to work. Forced vital capacity (FVC) and forced expiratory volume in one second (FEV_1) (Warren E. Collins Inc, Braintree, Mass) were measured and results compared with previously published standards.[6] Differences were considered significant by *t* test for *P* values of less than .05.

Results

Partial Airway Obstruction

The patients were divided into two groups. Group A consisted of 15 patients (11 men), aged 61 ± 11 years, (mean ±1 standard deviation [SD]) who had an incomplete airway obstruction such that a partial airway lumen could be visualized. Ten patients had squamous cell carcinoma of the lung, two had adenocarcinoma of the lung, one had a large-cell undifferentiated carcinoma of the lung and two patients had metastatic spread to the lung (one mucoepidermoid, one adrenal

TABLE 1.—*Results of Laser Treatment of Patients With Partial and Complete Endobronchial Malignant Obstruction*

	Group A Partial	Group B Complete
Before Laser		
No. patients	15	14
Age (yr)	61.0±11.0*	66.0± 7.0*
Dyspnea Index	3.4± 0.6	3.6± 0.5
Karnofsky (%)	45.0±15.0	28.0±11.0†
FEV_1 (% predicted)	56.0±22.0	46.0±14.0
FVC (% predicted)	68.0±21.0	47.0±16.0†
MMF_{25-75} (% predicted)	27.0±14.0	33.0±12.0
After Laser		
No. success (%)	13 (87)‡	5 (36)†
FEV_1 (% predicted)	67.0±27.0	48.0±15.0
FVC (% predicted)	76.0±24.0	49.0±17.0
MMF_{25-75} (% predicted)	62.0±24.0‡	50.0± 9.0‡
Dyspnea Index	2.6± 0.6‡	3.4± 0.5
Karnofsky (%)	60.0±15.0‡	29.0±16.0

FEV_1 = forced expiratory volume in 1 sec; FVC = forced vital capacity; MMF_{25-75} = maximal midexpiratory flow rate.

*Mean ±1 SD.
†Significant difference between two groups, $P < .05$.
‡Significant difference before and after laser treatment $P < .05$.

cell). In all, 11 patients had undergone one or a combination of radiotherapy, chemotherapy or lung surgery; four were untreated. Either cough or dyspnea or both were the major indications for laser treatment in ten patients, uncontrolled hemoptysis in three and unresolved atelectasis with abscess or pneumonia in two. In this group the Dyspnea Index was 3.4±.63 (mean ±1 SD) and the Karnofsky score was 45± 15% (mean ±1 SD) (see Table 1).

Before laser therapy, the FEV_1 was 1.6±0.7 liters (mean ±1 SD) and 56±22% predicted (mean ±1 SD). The forced vital capacity was 2.7±1.1 liters (mean ±1 SD) and 68±21% predicted (mean ±1 SD).

Figure 1 and Table 1 show the location of the tumor and incidence of successful laser therapy. Overall success that lasted one to six months was achieved in 13 of the 15 patients in a single operative procedure. After the initial laser treatment, nine patients have received additional laser therapy every one to three months for recurrent tumor. The postlaser therapy Dyspnea Index was 2.6±.63, which was significantly better from the initial Dyspnea Index ($P<.05$) and was associated with significant improvement in the Karnofsky score (Table 1). The most dramatic improvement occurred in a 43-year-old man with tracheal stenosis of 2.5 mm in diameter following tracheal resection and end-to-end anastomosis for squamous cell carcinoma. The stenosis occurred at the site of the anastomosis due to granulation tissue and malignancy. A tracheostomy failed and following a single laser therapy the diameter increased to 10 mm; subsequent monthly treatments for six months have been required to maintain this diameter (Figure 2). Other dramatic results included immediate cessation of hemoptysis or lessening of cough, dyspnea or atelectasis. Immediately postlaser therapy, the FEV_1 increased 900 ml and the FVC 1,400 ml following the treatment of a partially occluding right main stem bronchial lesion (Figure 3) in a 73-year-old man.

There was one operative death due to respiratory failure in a patient undergoing repeat laser therapy for recurrent tumor. He was terminally ill and in respiratory distress. Two patients died of massive hemorrhage within ten days of a laser treatment. Permission for autopsy was refused in both patients. Rigid bronchoscopy was used in only 3 of 15 patients.

Complete Airway Obstruction

Group B consisted of 14 patients (7 men) aged 66±7 years (mean ±1 SD) who had complete airway obstruction. All patients had undergone one or a combination of previous or concurrent radiotherapy, chemotherapy or a surgical procedure of the lung. Six patients had squamous cell carcinoma of the lung, seven had large-cell undifferentiated lung cancer and one had hypernephroma. Unresolved atelectasis-pneumonia was the major indication for laser therapy in three patients, hemoptysis in one and cough or dyspnea (or both) in the other ten patients. The Dyspnea Index was 3.6±0.5 and the Karnofsky score was 28±11%. The FEV_1 was 1.2±0.2 liters (46±14% predicted) and the FVC was 1.7±0.4 liters (47±16% predicted). The Karnofsky score and FVC were significantly ($P<.05$) worse in this group when compared with group A (Table 1).

Figure 1 and Table 1 show the location of the tumor

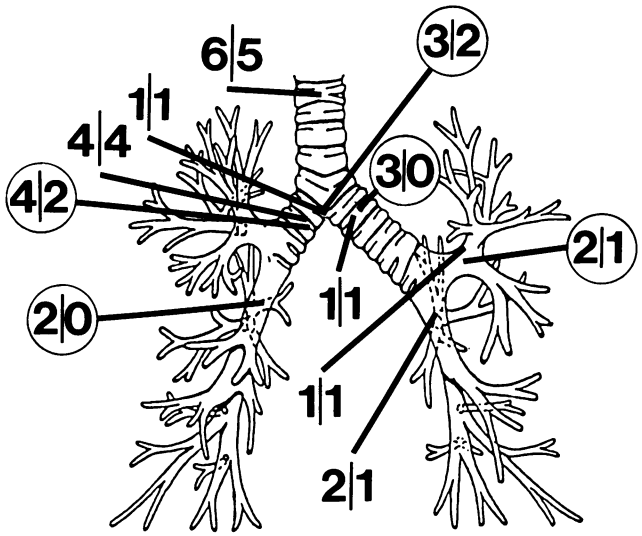

Figure 1.—The diagram shows the location and success rate for laser therapy in patients with partially occluded airway tumor and those with totally occluded airways **(circled)**. For each location the first number represents the total number of cases and the number after the diagonal slash represents the number of successfully treated cases.

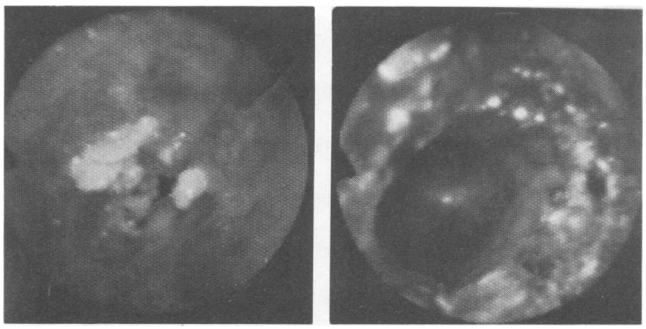

Figure 2.—Tracheal stenosis of 2.5 mm due to granulation and tumor tissue **(left)** and immediate improvement after laser therapy **(right)**. A tracheostomy was attempted but could not be accomplished because of extensive tumor growth.

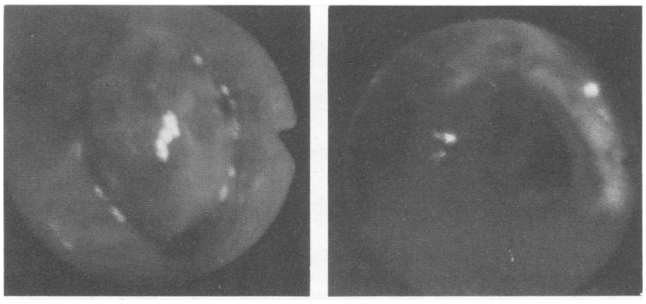

Figure 3.—Partially obstructed right main stem bronchus before **(left)** and after **(right)** laser therapy.

and incidence of successful laser therapy. Overall success that lasted from three to six weeks was achieved in only 5 of 14 patients after a single treatment. The post-laser Dyspnea Index was 3.4 ± 0.5. Of the five patients in whom the laser therapy was successful, each patient has subsequently required repeat treatments every three to six weeks for recurrent tumor and airway obstruction. There were two deaths, including one of complication in the perioperative period. Both patients were bedridden and terminally ill in respiratory distress, with a Dyspnea Index of 4, gasping respirations and Karnofsky scores of 15. The FEV_1 was 1.5 liters (58% predicted) and 1.0 liters (30% predicted) and resting arterial oxygen tension was 50 and 52 mm of mercury. There was complete obstruction of the right main stem bronchus with mediastinal spread in one case and complete obstruction of the carina and left main stem bronchus with mediastinal spread in the other case. In the latter case following partial opening of the left main stem bronchus, the partially inflated left lung on chest roentgenogram showed diffuse metastatic nodules. In this patient, during the laser treatment sparks from the burnt tissue ignited and destroyed the outer sheath of the fiberoptic bronchoscope. The bronchoscope was immediately removed and no obvious tissue burns resulted. However, both patients succumbed to a respiratory death with progressive hypoxemia within three days of the laser treatment. Rigid bronchoscopy was used in 5 of the 14 patients.

Discussion

The results of this study indicate that the Nd-YAG laser may provide immediate palliative relief in 13 of 15 symptomatic patients with incomplete airway obstruction associated with cough, dyspnea, hemoptysis and lung collapse. The procedure is purely palliative and may provide temporary relief for one to six months after a single treatment, depending on malignant recurrence or metastasis. However, we had only limited success in 5 of 14 patients with complete airway obstruction.

It is difficult to compare our results with previous reports of about a 75% success rate in 72 patients by Toty and co-workers[1] and in 63 cases by Dumon and associates[2] because these experienced French investigators did not separate patients by extent of airway obstruction. However, in the report by Hetzel and colleagues[3] they noted a success rate in 10 of 19 patients with partial airway obstruction and only short-lived improvement in two of nine patients with complete airway obstruction. Based on this and our own results, it would appear that patients with complete airway obstruction respond poorly to laser therapy. Because as a group they have more extensive tumor involvement, they have a higher Dyspnea Index, a lower Karnofsky score and further impairment in lung function. This creates additional hazards and they remain at high risk and poorly tolerate general anesthesia and rigid bronchoscopy, which is the recommended operative procedure.[1,2] Other than for control of hemoptysis, attempted recannulation and subsequent reexpansion of lung due to a completely obstructed bronchus from malignancy yields poor results. It is technically very difficult to clearly separate the obstructing tumor from the bronchial wall, which is often invaded with tumor, and this often precludes visual perception of the branching of distal airways. Furthermore, in many cases combined extrinsic tumor compression of the airway further complicates and reduces the effectiveness of laser therapy. In one patient we were able to recannulate a completely obstructed bronchus but the lung never reexpanded.

We remain concerned about the potential relationship between laser therapy and pulmonary hemorrhage. Unfortunately autopsy permission was not granted in the two patients who had hemorrhage ten days after laser therapy and this dilemma cannot be resolved. It is quite possible the hemorrhage was a result of tumor invasion into a major blood vessel in the mediastinum. Alternatively, because of the physical properties of the Nd-YAG laser that favor decreased surface absorption and increased penetration with both forward and backward scatter into tissues, hemorrhagic complications in surrounding blood vessels must be considered. In a preliminary report McDougall and Cortese[7] noted two cases of fatal hemorrhagic complications from laser therapy for bronchogenic carcinoma.

We are also concerned about the dangers of the laser or burning tissue igniting the fiberoptic bronchoscope. In a recent report a similar complication is described.[8] Obviously damage to the fiberoptic bronchoscope can be avoided if rigid bronchoscopy is used. When the fiberoptic bronchoscope is used, careful attention at all times must address the location and cleanliness of the laser fiber tip. Furthermore, while nonflammable anesthetic agents are used, it is sometimes unavoidable to use a high concentration of inspired oxygen.

European investigators[1,2] strongly favor the use of the rigid bronchoscope to deliver the laser fiber and to provide better access to the involved tumor area for aspiration, biopsy, cutting, control of hemorrhage and ventilation. However, the drawback is the usual requirement for general anesthesia with either intravenous or inhalational agents, or both. Unfortunately there are air leaks, and decreased gas exchange with ventilating rigid bronchoscopes and monitoring of arterial blood gases is needed. While we have not used jet ventilation this is the preferred technique of Toty and associates.[1] Dumon and co-workers[2] favor administering sedatives intravenously while patients are still breathing on their own because many of these patients are poor candidates from a respiratory aspect for general inhalational anesthesia. Our three patients in whom respiratory failure developed and who died postoperatively were terminally ill with respiratory distress preoperatively and required rigid bronchoscopy and

general anesthesia because of the extent of their endobronchial lesions. Whether successful results can be achieved with fiberoptic bronchoscopes remains to be seen. Our good results in patients with partial obstruction would appear to support this.

Finally, we must address the issue of the clinical usefulness of this procedure. Once the technical aspects are perfected, the procedure is well tolerated by patients and can be done on an outpatient basis, thus avoiding hospital care costs. It appears to offer excellent palliative relief in patients with partially obstructed airways, especially when other forms of therapy may no longer be advisable. Less than optimal results are noted in patients with totally obstructed airways. Whereas most of the patients in this study group underwent laser therapy for tumor recurrence following their initial operation, chemotherapy or radiotherapy, the role of initial laser therapy before these modalities needs to be evaluated.

REFERENCES

1. Toty L, Personne C, Colchen A, et al: Bronchoscopic management of tracheal lesions using the neodymium yttrium aluminum garnet laser. Thorax 1981; 36:175-181

2. Dumon J-F, Reboud E, Garbe L, et al: Treatment of tracheobronchial lesions by laser photo resection. Chest 1982; 81:278-284

3. Hetzel MR, Millard FJC, Ayesh R, et al: Laser treatment for carcinoma of the bronchus. Br Med J 1983; 286:12-16

4. Medical Research Council: Questionnaire on Respiratory Symptoms. London, Medical Research Council, 1966

5. Karnofsky DA, Burchenal JH: The clinical evaluation of chemotherapeutic agents in cancer, *In* Macleod C (Ed): Evaluation of Chemotherapeutic Agents. New York, Columbia University Press, 1948

6. Morris JF, Koski A, Johnson LC: Spirometric standards for healthy nonsmoking aduits. Am Rev Resp Dis 1971 Jan; 103:57-67

7. McDougall JC, Cortese D: Neodymium-YAG laser therapy of malignant airway obstruction. Mayo Clin Proc 1983; 58:35-39

8. Casey KR, Fairfax WR, Smith SJ, et al: Intratracheal fire ignited by the Nd-YAG laser during treatment of tracheal stenosis. Chest 1983; 84:295-296

Medical Practice Questions

EDITOR'S NOTE: *From time to time medical practice questions from organizations with a legitimate interest in the information are referred to the Scientific Board by the Quality Care Review Commission of the California Medical Association. The opinions offered are based on training, experience and literature reviewed by specialists. These opinions are, however, informational only and should not be interpreted as directives, instructions or policy statements.*

Rectal Mucosal Replacement

QUESTION:

In cases of chronic ulcerative colitis and familial polyposis, is rectal mucosal replacement with construction of a rectal reservoir considered established medical practice or is it investigational?

OPINION:

In the opinion of the Scientific Advisory Panel on General Surgery, rectal mucosal replacement with construction of a rectal reservoir is considered accepted medical practice for the treatment of chronic ulcerative colitis and familial polyposis, when carried out by surgeons skilled and experienced in this technically demanding procedure.

While the procedure has been done for over a decade, with various forms of reservoir formation being recommended more recently, the panel noted that numerous publications still cite unfavorable results and revisions necessary in the technique. Further study is required to resolve such problems as the selection of appropriate candidates for the operation, the choice of optimal technique and the significant immediate and long-term complications. Additionally, a longer period of follow-up is needed to evaluate the results of this procedure with regard to frequency of defecation, need for reoperation and long-term failure.

This is a promising, well-conceived procedure, the final evaluation of which will take several years.